Effects of COVID-19 on the electricity sectors of Ukraine and Hungary: challenges of energy demand and renewables integration

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Abstract—**This paper attempts to analyze impacts of the COVID-19 and associated lockdowns on the Ukrainian and Hungarian energy sectors, focusing on changes in electricity consumption patterns, share of renewables in energy balance, and readiness of the national power systems in the face of future possible global health crises. Specifically, this work draws parallels between electricity usage, national quarantine restrictions and changes in economical, business, social, and industrial activities. The challenges of rising installed capacity and generating potential of alternative energy sources are discussed with regards to reduced energy demands during the pandemic. The results of this study can be of potential interest for policymakers, regional transmission organizations and stakeholders to prepare for similar situations in future.**

Keywords—COVID-19, coronavirus, electricity consumption, electricity market, energy demand, renewable energy

I. Introduction

The coronavirus disease (COVID-19) has rapidly spread around the world in 2020, effecting 188 countries and regions [1] and prompting the World Health Organization (WHO) to declare it as public health emergency of international concern [2]. As many other national economies, the governments of Ukraine and Hungary have responded to the global pandemic with severe confinement measures, including operational restrictions for businesses, universities, retail sector, restaurants, recreational facilities, and other crowd gathering activities. These quarantine restrictions have caused significant reductions in daily commercial and industrial power consumption since multiple factories have halted operations, and businesses have switched to work-from-home option. On the contrary, the portion of residential electric energy demand has risen.

Several reports from both peer-reviewed [3] and non-peer-reviewed sources [4]-[11] (i.e. news media, government agencies, professional communities, regional transmission organizations etc.) have highlighted the adverse impact on the electricity and renewable energy sectors worldwide, including operational reliability degradation, decreasing wholesale prices, and delayed investment activities. Especially noticeable reduction of energy consumption has been supervised in areas with large commercial activity [4]. In many parts of the world peak demands have drastically dropped by 20% [5].

Pioneering insights can be obtained from the Italian case, where the virus was first confirmed to have spread to on 31 January 2020, and in February eleven municipalities in northern Italy were placed under quarantine [6]. The following Prime Minister's Decree of 9 March 2020 affected the whole national territory. Results of the shutdown were substantial. During the first two days of the national shelter-in-place, the Italian system recorded reduction in weekday energy use of 14% compared to that of the previous week and the same week in 2019. During days five through eight of the national shelter-in-place, the system operators recorded reduction of 21% for daily energy use relative to the same week in 2019 [7]. The decreased demand during days five through eight, in turn, influenced the national generation mix, with the descent in thermal energy production by 15% and the ascend in the load share covered by renewable energy sources (RESs) from 7.8% to 8.7% [8]. Another European example is Spain, where a state alarm was declared on 14 March 2020. During the following four days the demand for electrical energy plummeted by 8.2%, falling down by 15% by the seventh day, compared to the same days of the week preceding and the same week in 2019 [9]. During the second week of the national state of alarm the Spanish system recorded reductions of 7% for peak and 10% for daily energy usage relative to the same week in 2019 [7]. During the first days of city- and statewide shutdowns in New York and California, these states recorded a 3-7% decrease in peak demand and energy use, compared with the prior week and prior years, with major impact observed during morning peak hours [10]. During the following weeks, the reduction in electricity consumption continued across all U.S. markets, ranging from 6.36% to 10.24% in April and from 4.44% to 10.71% in May, while in June the energy consumption rates rose slightly due to mitigation of the quarantine measures [11].

In the work [11] an open-access data-hub to track and analyze the intensity and dynamics of the pandemic's impact on the U.S. electricity sector has been introduced. The authors of this study have suggested that trace of energy demand is strongly corelated with the rise in the number of COVID-19 cases, the size of the stay-at-home population (social distancing), population of on-site workers, and mobility in the retail sector (representative of the share of commercial electricity use) and emphasized the following patterns.

- The largest portion of the drop in electricity consumption is caused by lessening of people's daily visits to retail establishments, including miscellaneous store retailers, restaurants and eating places, automobile dealers, gasoline stations, grocery stores, health and personal care stores etc. The mobility in the retail sector is referred as the most significant and robust factor influencing energy demand across all cities [4]. It is closely connected with the practice of social distancing and home isolation by citizens.

- The number of newly confirmed COVID-19 cases does not have a strong direct influence on changes in energy demand. However, this indicator can influence the electricity consumption rates indirectly, through such factors as commercial activity and social distancing.
- High sensitivities to some of the aforementioned influencing factors may be observed in cities with a mild overall reduction in electricity consumption.

The paper [3] explores how the pandemic affected the operation of the Israeli, Estonian, and Finnish power grids and underlines some patterns of consumption changes that may be caused by the emergency regimes. Relative change in the overall Israeli weekly consumption for the periods of 2-8 March (before emergency state was declared) and 30 March-5 April (after the declaration of the state of emergency) dropped by –9.9% for residential sector and by –23.85% for business sector, while industrial consumption demonstrated just a minor increase of +1.11%. As for Estonian power system, for the same time periods the joint drop of –14.97% was supervised in business and industrial sectors, while the residential consumption strengthened by +3.76%. In Finland the consumption in March 2020 was lower compared to March 2019, and the consumption profile of 2020 declines from week to week as the number of people in quarantine increases [3].

The long-term effects of the pandemic on the energy sectors are currently scantly investigated, and in-deep studies will probably take many years to come [11]. Given the rapid spread of COVID-19 and the corresponding policy changes, there is a need in more rigorous scholarly work on the topic. This paper attempts to analyze impacts of the pandemic on the Ukrainian and Hungarian power systems, focusing on changes in energy consumption patterns, the role of renewables in energy balance, and the readiness of national power grids in the face of future possible global health crises. The results of this study can be potentially useful for policymakers and regional transmission organizations to prepare for similar situations in future.

II. Impact of the pandemic on electriciry sectors

A. *Characteristics of the Ukrainian and Hungarian power systems*

The Integrated Power System (IPS) of Ukraine is a system of nuclear, thermal, hydroelectric and pumped storage power plants, cogeneration plants, RES-based power plants, Ukrenergo's trunk power grids and power distribution networks (oblenergo), unified by the common electricity and heat generation, transmission and distribution mode [12]. It includes 4 nuclear power plants (NPPs), 14 large thermal power plants (TPPs), 7 major hydro power plants (HPPs) and dozens of solar, wind and biofuel power plants with total installed capacity (IC) of 53.87 GW. The IPS of Ukraine is interconnected with the power networks of Belarus, Moldova, Russia via interstate power transmission lines, while «Burshtyn TPP Island» operates in parallel with the synchronous grid of Continental Europe [13]. The «Burshtyn TPP Island» has a technical reserve of 650 MW for cross-border power exchange with Romania, Hungary, and Slovakia. The IC mix of the Ukrainian power system is demonstrated in Fig. 1, and its characteristics relevant for this study are given in Table I.

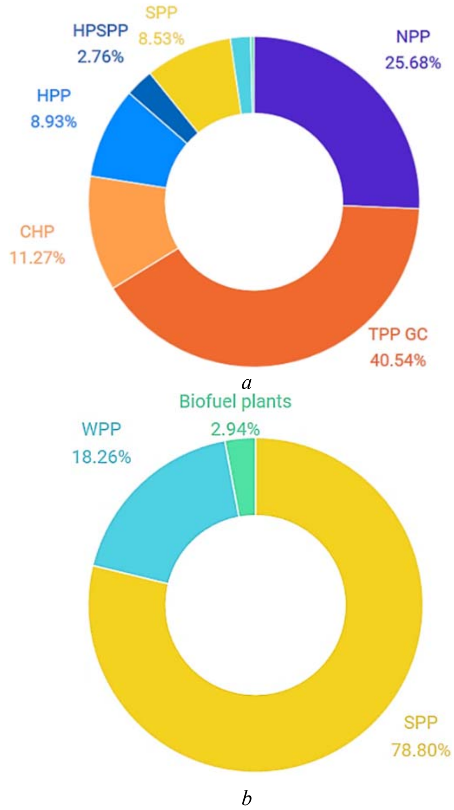

Fig. 1. IC mix of the Ukrainian power system: (a) overall IC mix; (b) RES-based IC mix. Here TPP GC is the thermal power plant, generating company; HPSPP is the hydroelectric pumped storage power plant; CHP is the combined heat and power; SPP is the solar power plant; WPP is the wind power plant

The Hungarian energy system is also characterized by a diverse composition of energy sources. Almost half (49.24%) of the energy produced in domestic power plants in 2019 came from NPPs, the natural gas-fired power plants are in second place with 27.11%, coal-lignite-fired power plants are in third place with 12%. The share of the outdated coal-lignite-fired sources is still considerable, but they are to be removed from the system and replaced with up-to-date and environmentally friendly technology [14]. The share of renewable energy within the power plants pool is about 12%. The sources of Hungarian domestic energy production are shown in Fig. 2a.

The national energy system of Hungary is a part of the synchronous area of Continental Europe and interconnected with the power networks of Austria, Slovakia, Ukraine, Romania, Serbia, and Croatia. So far there is no energy exchange with Slovenia, but Slovenian-Hungarian interconnections are going to be set and may have an impact on the cross-border flows in the coming years. The IC mix of the Hungarian power system is demonstrated in Fig. 2b, and its main features are summarized in Table I.

B. *The effect of COVID-19 pandemic on energy consumption patterns in Ukraine and Hungary*

Economical, business, social, and industrial activity in a state is heavily dependent on the electricity usage. Information on relative differences in energy demands between 2020 and 2019 for Ukraine and Hungary is shown in Fig. 3. The data is retrieved from [17] and demonstrates the evolution of change in peak-hour electricity consumption since the beginning of March. The electricity tracker [17] is focused on peak-hour consumption (from 8 a.m. till 6 p.m.), when the most economic activity would normally take place. Only working days are considered, while weekends and public holidays are disregarded. The data is adjusted for temperature differences between 2020 and 2019 by means of a polynomial function of relationship between electric energy load and temperature for each country considered. The factor of daily temperature is one of the crucial points for analysis of this nature, since energy consumption can fluctuate significantly depending on usage of air conditioning equipment, water heating/cooling installations.

General insights into the impact of the global pandemic and associated lockdowns can be obtained from Fig. 3. In Ukraine the energy consumption started its drop in early March, after the first confirmed COVID-19 case was announced on 3 March. A more substantial decline was recorded during the weeks following the emergency regime declaration (12 March 2020). Reduction in energy

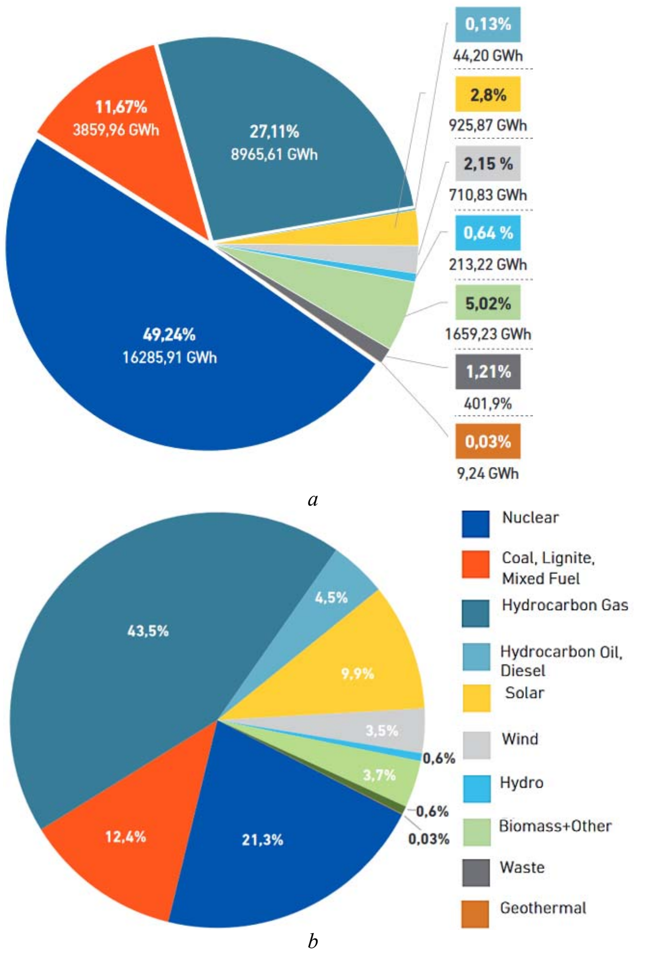

Fig. 2. Energy capacities of the Hungarian power system: (a) the sources of domestic energy production (b) IC mix

consumption fastened after 2 April 2020, when the Cabinet of Ministers of Ukraine re-enacted its resolution "On Prevention of Spread of Acute Respiratory Disease COVID-19 Caused by SARS-CoV-2 Coronavirus", which severely restricted the freedom of citizens, in particular, forbidding to visit recreation areas, move in groups of more than two people etc. [18]. The surprising spike of +3% during the last week of April might be partially explained by an uneven load schedule and widely fluctuated electricity generation from SPPs and WPPs, which evoked a complication in balancing of the power system, as it was reported by the National Power Company "Ukrenergo" [19]. However, the source [20] provides different data for the same week, which will be discussed further. The energy consumption in Ukraine has started its moderate rise after a number of restrictions were lifted on 11 May, including the re-opening of parks, squares, recreation areas, hairdressers, cafes and restaurants with outdoor tables. These trends correspond to the assumption that the largest portion of the drop in energy demand comes from the cutback in individuals' daily visits to retail establishments as they adopt to social distancing and home isolation [4]. By comparison, the number of new confirmed COVID-19 cases does not seem to have a strong direct influence on changes in electricity consumption, since it has been rising stably since the middle of May despite the nonstop growth in new coronavirus cases [21].

According to the results of the first half of 2020, compared to the same period in 2019, the decrease in electricity consumption (net, excluding grid losses) was 4.9% (58.6 billion kWh vs. 61.6 billion kWh) [20]. The comparison of energy demand in Ukraine in 2018-2020 is shown in Fig. 4.

TABLE I. CHARACTERISTICS OF THE UKRAINIAN AND HUNGARIAN POWER SYSTEMS

Characteristic	Ukraine	Hungary
Population, mln.	41.786 (as of June 2020) [15]	9.773 (as of 2019) [16]
Total area, km^2	603628	93030
Date of emergency state declaration	12 March 2020	11 March 2020
Details of grid connection	AC connections with Belarus, Moldova, Russia, Romania, Hungary, and Slovakia	Part of ENTSO-E. AC connections with Austria, Slovakia, Ukraine, Romania, Serbia, and Croatia
Total installed generation capacity, MW	53874.62 (as of July 2020)	9441.8 (as of December 2019) [14]
Share of RESs*, MW	12128.2 (as of 2020)	1668.9 (as of December 2019) [14]
Share of RESs excluding hydro, MW	5829.2 (as of 2020)	1611.1 (as of December 2019) [14]

*Including solar, wind, biofuel, and hydro power plants

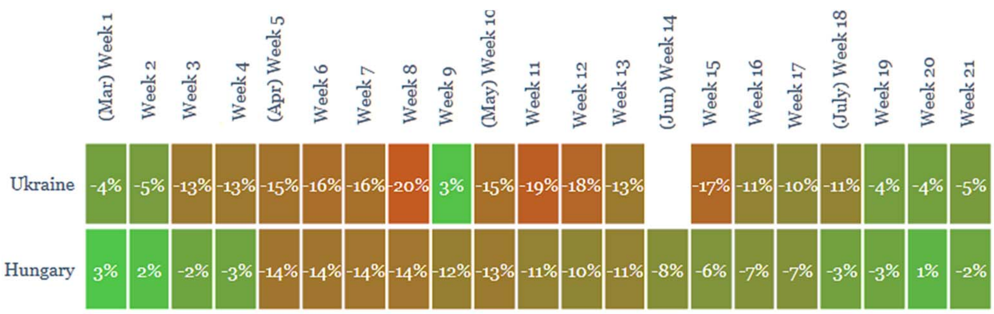

Fig. 3. Changes in 2020 consumption relative to 2019 in Ukraine and Hungary

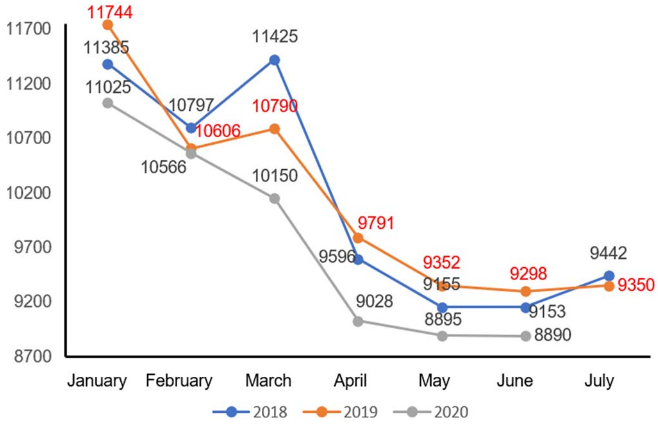

Fig. 4. The comparison of energy demand in Ukraine in 2018-2020, TWh

In June almost all consumer groups reduced consumption, except for the residential sector, chemical and petrochemical industries, as well as agricultural loads (+11.5%, +7%, and +0.3% compared to June 2019). The most noticeable decline during this period was demonstrated by transport sector (–24.2%), machine-building industry (–20.7%), utilities (–19.2%), other non-industrial consumers (–11.6%), food and processing industry (–8.7%), fuel industry (–6.9%). In general, the level of industrial consumption in June 2020 decreased by 4.2% compared to June 2019. The structure of electricity consumption in June 2019 and 2020 in TWh is given in Fig. 5, and energy demands of the industrial group of consumers in June 2019 and 2020 are compared in Fig. 6.

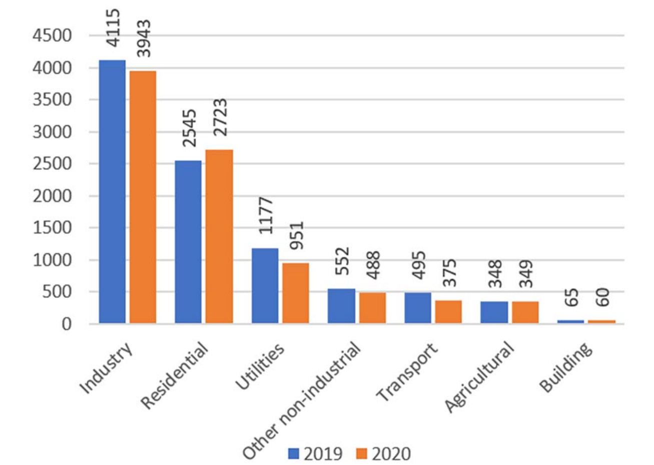

Fig. 5. The structure of electric energy consumption in Ukraine in June 2019 and 2020, TWh

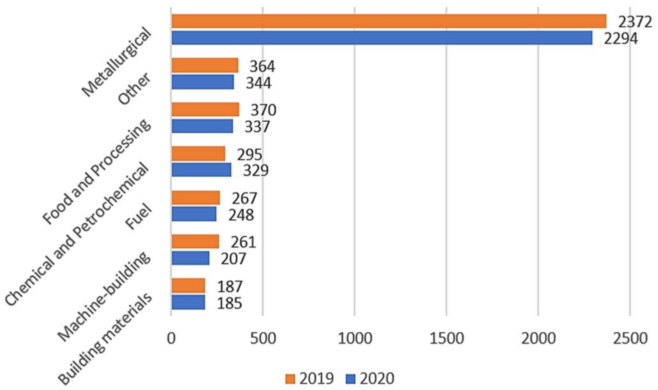

Fig. 6. Comparison of electric energy consumption of the industrial group of consumers in Ukraine in June 2019 and 2020, TWh

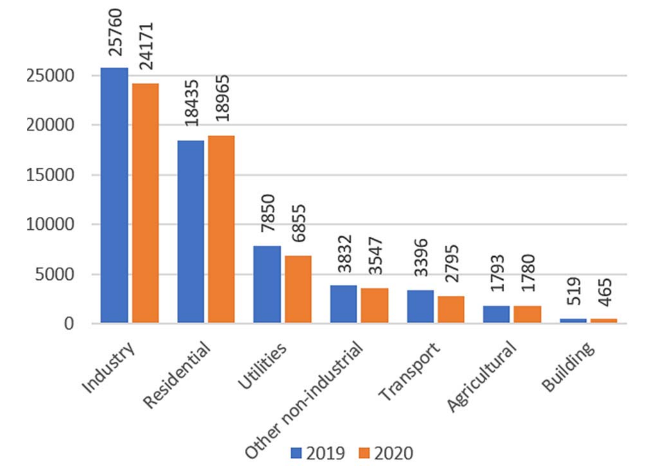

Fig. 7. The structure of electric energy consumption in Ukraine in January-June 2019 and 2020, TWh

In general, the level of consumption of the entire industry in January-June 2020 compared to the same period of 2019 decreased by 6.2%, from 25.76 TWh to 24.17 TWh. In particular, the largest decrease in electricity consumption is for machine-building industry – by 20% (1564.8 TWh vs. 1955.7 TWh) and for transport – by 17.7% (2794.8 TWh vs. 3396.1 TWh). At the same time, in the first half of 2020 household electricity consumption rose by 2.9% (18.97 TWh vs. 18.4 TWh) and in chemical and petrochemical industry – by 16.4% (1960.5 TWh vs. 1684 TWh). The structure of electricity consumption in January-June of 2019 and of 2020 in TWh is provided in Fig. 7.

Hungary's total electricity consumption reached 45.7 TWh/year in 2019, and according to the forecast it will exceed the level of 50 TWh/year in the coming years [14]. The rapid spread of electricity-based household and industrial technologies and digitalization are the main drivers of this growth. Although the share of imported energy decreased somewhat in 2019, however, its importance in the Hungarian market has not changed significantly, it is still around 30%. The National Energy Strategy (NES) sets a level of 20% by 2030. The decrease in imports was offset by domestic production.

As per Fig. 3, in case of Hungary energy consumption started to descend right after the declaration of state lockdown on 11 March 2020. The lowest level of energy demand was supervised between 30 March and 26 April, which was 14% lower compared to the same period of 2019. A growth of energy demand began in early May, and in mid-June Hungary reached the same level of energy consumption as in June 2019 [17]. The rebound in electricity consumption at Hungarian electricity markets is correlated with partial reopening of the economy. According to the results of the first half of 2020, compared to the same period in 2019, the decrease in electricity consumption in Hungary (net, excluding losses in the grid) was 3.62% (22.1 billion kWh vs. 22.9 billion kWh) [22]. The comparison of energy consumption in Hungary in 2018-2020 is shown in Fig. 8.

III. Effects of Renewable Energy Sources

Increasing share of RESs has changed the structure of generation in the power systems of Ukraine and Hungary. In Ukraine in March 2020, compared to March 2019, generation at wind and solar power plants has doubled – to 863 TWh [23]. This trend is now exacerbated by declining consumption due to seasonal warming and quarantine. In 2020, compared to 2019, the generation from RES is projected to almost double to 10.284 TWh. During 2019 the installed capacity of SPPs and WPPs in Ukraine increased 2.7 times and reached 4.7 GW, which is the largest amount that the state power system can currently accept without serious operational deviations. As of the beginning of April 2020, the IC of RES has already reached 5.2 GW. The dynamics of change of generating capacity of RESs in Ukraine is shown in Fig. 9.

In Hungary, the number of SPPs and WPPs is growing rapidly as well, and at the end of 2019 the share of RESs in the country's energy balance was 12.35% [24]. In 2019 the share of SPPs in Hungarian power grid jumped up almost three times and reached 936.3 PW, compared to 333.5 MW in 2018. Capacities of WPPs and biofuel power plants also increased: from 324.9 MW and 290.7 MW in 2018 to 327.5 MW and 320.3 MW in 2019, respectively [14]. In 2020 a further abrupt elevation of the quantity of solar generating units is expected.

Alongside with the increasing RES capacities, abnormally low electricity consumption during the pandemic complicates management and control of generation and may negatively affect system's reliability and resiliency. When electricity consumption is exceptionally low, system operators must shut-down conventional power plants that are normally operated, until a normal consumption level is restored [3]. Consequently, when less power plants are being used, the ability to control reactive power and voltage levels narrows down, and the frequency response is limited.

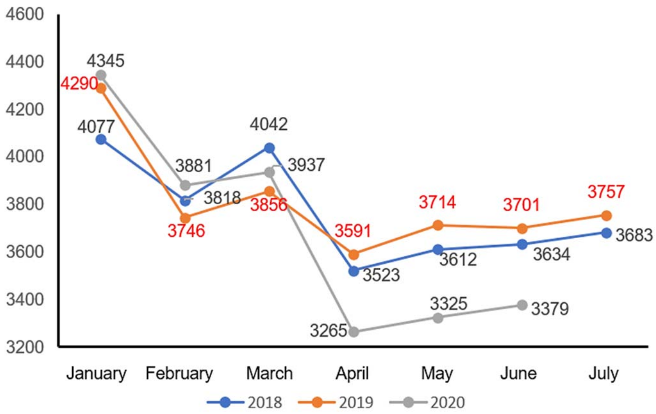

Fig. 8. The comparison of energy demand in Hungary in 2018-2020, TWh

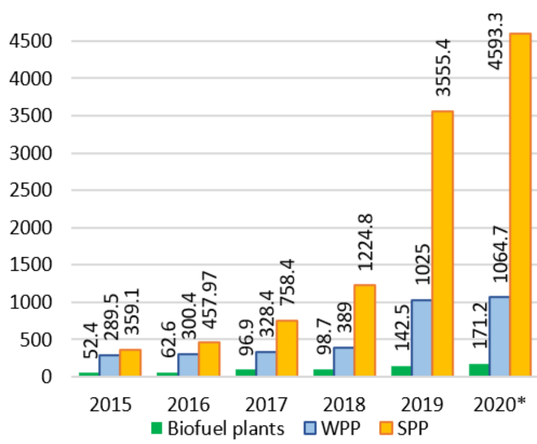

Fig. 9. Installed capacity of renewables in Ukraine in 2015-2020, MW (* values as of 31 June 2020)

The Ukrainian state has committed itself to buy out all the electricity generated by RESs, regardless of the energy demand [23]. It also released RES producers from liability for balance sheets and guaranteed them full compensation for lost profits in the event of possible restrictions. Such circumstances and the high "green" tariff stimulate RESs to generate the maximum possible output. Thus, RESs are always present in the generation structure with the maximum possible capacity level regardless of fluctuations in power consumption. In these circumstances the SPPs and WPPs, given their low predictability, create considerable risks of power imbalance in the IPS of Ukraine [25], [26]. Balance violations are regulated by the activation of TPPs and HPPs offer applications in the balancing market segment. When the deviations causing a surplus of electricity last for a significant part of the day and there are not enough unloading offers on the balancing market, dispatchers are forced to issue operational safety commands aimed at reducing TPP, HPP and NPP capacities.

If imbalances last for 1-2 hours and all other tools for their settlement are exhausted, there are grounds for RES generation restrictions. In Ukraine from November 2019 to February 2020 RES restrictions were applied three times. Solely in March 2020 SPPs and WPPs were curtailed four times. However, daily electricity consumption in early March fell from more than 400 TWh to 395 TWh. In the first five days of April 2020, curtailments were applied almost on a daily basis, with both duration and magnitude increasing. By the end of the year the volume of restrictions will increase both due to reduced electricity consumption (natural seasonal factors, quarantine effects, reduced economic activity) and to increasing amounts of energy released by RESs, which may exceed a total of 1 TWh [23].

For effective integration of solar and wind power technologies without the system's imbalance risks it is necessary to satisfy the following measures [23]: a) introduce RES responsibility for imbalances; b) construct new maneuvering capacity with a short startup time; c) deploy energy storages of large capacity to provide frequency maintenance reserves; d) restrain volumes of annual support quotas for business entities, which produce energy from alternative energy sources so, that they do not exceed the capacity of the IPS of Ukraine to fully integrate them without limitations of power output.

CONCLUSIONS

This paper provides an insight of the impact of COVID-19 on the Ukrainian and Hungarian electricity sectors and assesses its intensity and dynamics. As the coronavirus outbreak emerged in Ukraine and Hungary, the electricity usage dropped as businesses shuttered and people adopted to the stay-at-home mode. In both countries energy demands started to drop almost immediately after the national emergency announcements. In contrast with downturns in energy consumption by industry and business, a significant increase in residential electricity consumption has been detected. The mobility in the retail sector, the size of stay-at-home population (social distancing code), and slower commercial activity seem to be the key indicators effecting the trace of the electricity consumption. All these indicators are highly influenced by the preventive actions and policies being established by the national governments with the aim to decelerate the coronavirus spread. By comparison, the number of new confirmed COVID-19 cases does not seem to have a direct impact on electricity consumption.

Both Ukraine and Hungary are experiencing constant growth of renewables' capacity in the recent years. Additionally, abnormally low electricity consumption makes the relative share of RESs even more significand, which complicates management and control of a power system and may lead to reduced reliability and resiliency. A high portion of intermittent and low predictable RESs in a country's generation mix creates risks of power imbalances. Balance violations are usually regulated by the activation/deactivation of conventional TPPs and HPPs. In turn, smaller amount of traditional power plants in operation means reduced spinning reserve and lower rotational inertia. For enough big energy markets of Ukraine and Hungary, which are interconnected with the neighboring power grids, including the bulk synchronous area of Continental Europe, the probability of abnormal frequency deviations is low. However, for small and islanded energy markets that can be an issue.

The rapid growth of RES capacity under the circumstances of reduced energy demand and in the absence of quickly maneuverable reserves leads to restrictions of SPPs and WPPs. For effective integration of RESs without the risk of imbalance it is necessary to construct new maneuvering capacities with a short startup time and reinforce the grid with energy storage. However, these measures require high investments and should be economically proved. For effective leveraging of energy production from alternative energy sources it is crucial to provide a wise governmental policy. For example, support quotas for RES business entities should be in consonance with the capacity of a national power system.

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